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THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PLATE IX

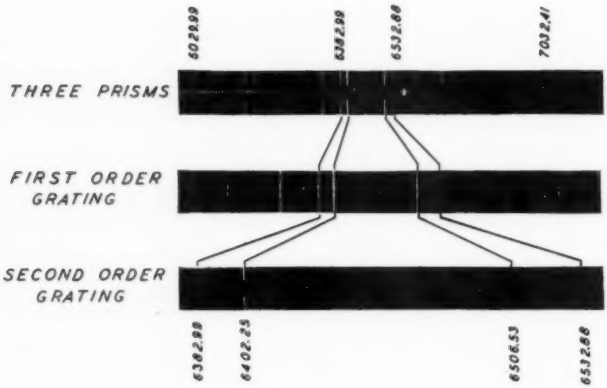

FIGURE 4

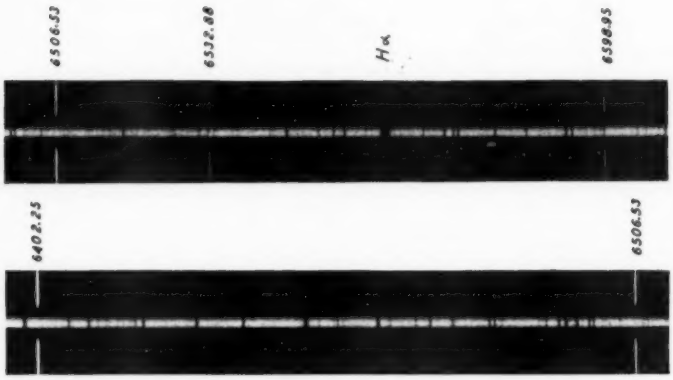

FIGURE 6

Fig. 4.—The Spectrum of Neon, giving a Comparison of Dispersions.
Fig. 6.—Second Order Grating Spectrum of α Bortis.

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ON THE USE OF ALUMINUM-ON-GLASS GRATINGS IN THE VICTORIA STELLAR SPECTOGRAPH

By C. S. BEALS and A. MCKELLAR
(with Plate IX)

A NUMBER of problems studied at the Dominion Astrophysical Observatory in recent years have indicated the need for higher dispersion, particularly in the visible and longer wavelength regions. One such investigation may be mentioned, namely the discovery of the duplicity of the interstellar calcium lines in the spectra of some of the Orion stars and ρ Leonis.[1] This made it very desirable to examine the interstellar D-lines of sodium in these same spectra to determine whether they showed a similar structure. The dispersion and resolving power then available in the yellow region of the spectrum with our three prisms were quite inadequate to resolve such close lines, separated by about 0.2 angstrom units.

The obvious step was to use a diffraction grating. The observatory possessed a speculum-metal plane grating ruled by Anderson in 1912, of a suitable size and ruled 15,000 lines to the inch. As such matters were considered until a very few years ago, it has one unusually bright first order. A temporary wooden mounting was constructed for this grating some three years ago and with this arrangement a few spectrograms were obtained of α Cygni. Although these were of good quality and exhibited satisfactory definition, the reflecting power of the grating was low and its speed insufficient for obtaining spectra of any but the very few

[1] C. S. Beals, *M.N.*, vol. **96**, p. 661, 1936.

brightest stars. Professor R. W. Wood has recently been ruling very fine gratings on chromium-aluminum surfaces evaporated onto pyrex glass blanks. Not only are these surfaces of high reflecting power and apparently quite durable, but Professor Wood has been able to control to a greater extent than has hitherto been possible the partition of the light in different orders. We were fortunate in being able to secure from him in June, 1936, a grating of this type on a circular blank, with a ruled surface about 3¼ inches square (15,000 lines to the inch) in which one first order is extremely strong. While this grating gave excellent performance and was a definite advance over the three prism arrangement, the need was felt for still higher resolving power and so last November, again through the courtesy of Professor Wood, we obtained a similar grating possessing one very strong second order. The present paper deals with the mounting and performance of these latter two gratings.

The problem of mounting a grating in the Victoria spectrograph is of interest because it must be set up behind the first prism instead of behind the collimator lens. This is made necessary by the structure of the spectrograph frame. The mounting of the grating in the usual place with respect to the collimator would necessitate the removal of a considerable area of one side of the spectrograph. This was not considered advisable since it probably would seriously impair the rigidity of the whole instrument. Thus the optical path in the mounting to be described is of the form shown in Figure 1, in which the diagram is that for the yellow region and our first order grating.

In Figure 2 is shown the working drawing used in constructing the grating mounting and a photograph of the completed instrument with the grating in place is shown in Figure 3. The base plate is made of steel, the turn table of brass and the actual grating-holder of aluminum. The most noteworthy point is that the mounting is of such a form that it fits precisely the position usually occupied by the camera when the single-prism form of the spectrograph is employed. Its position is fixed by the same four bolts and the dowel pin as would be that of the camera. With the grating in place as described, the camera is placed in the position it occupies when the three-prism form of our universal spectro-

graph is used. Then different spectral regions are very simply found by rotating the turn table, and with it the grating, by means

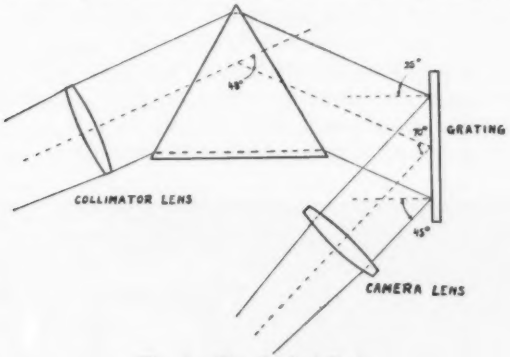

Fig. 1.—The Optical Path.

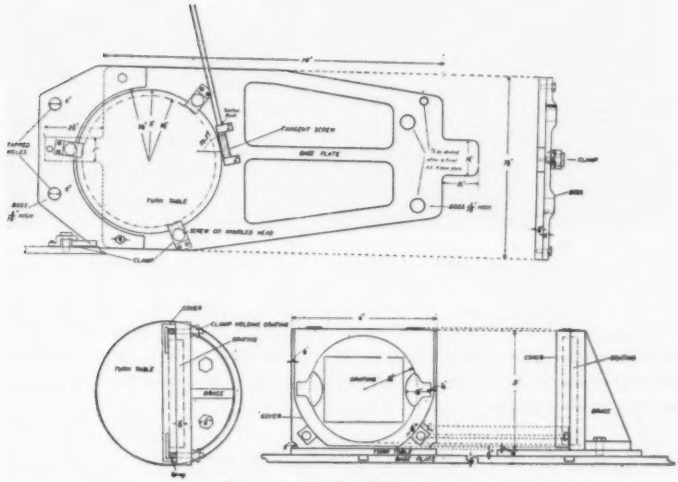

Fig. 2.—Grating Mounting.

of the tangent screw shown in the figure. A long handle on the tangent screw makes it possible to do this while viewing the comparison spectrum with an eyepiece. The grating, as is evident

from the diagram, fits into a circular recess in the aluminum casting and is held in place there by two hook clamps. When not in use, the grating is protected by a hinged cover which can be opened or closed while the grating is mounted in the spectrograph. Changing the spectrograph from the one-prism to grating form is simpler than changing to two or three prisms because the grating-holder can be handled more easily than the prisms and in the former operation the deviation of the prism-train need not be altered.

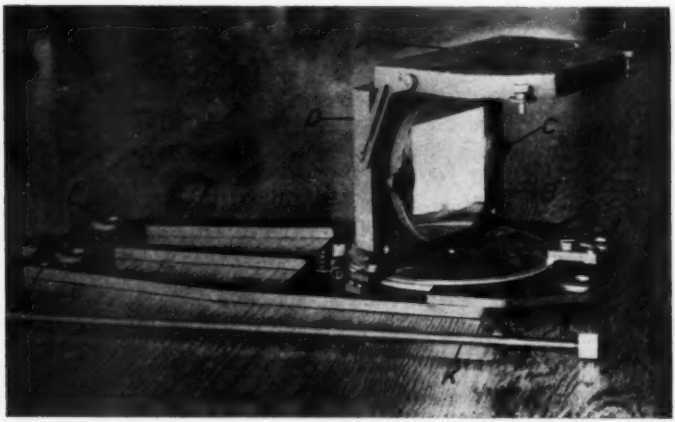

Fig. 3.—THE GRATING MOUNTING. *A*, Protective covering for grating; *B*, Grating; *C*, One of the two hook clamps for holding the grating in place; *D*, Aluminum casting with recess for holding grating; *E*, Brass turn table; *F*, Tangent screw; *G*, One of the three clamps for holding turn table at any required position; *H*, Steel base plate; *I*, Two of the four bolt holes for holding the grating mounting in the spectrograph; *J*, Dowel pin hole; *K*, Long rod for turning tangent screw.

scattered light and exhibit no ghosts of appreciable intensity. A test of reflecting power in the ultra-violet and freedom from scattered light was made on the strong first order grating by setting it up in a Littrow-type mounting with a quartz lens of focal length 10 feet. With a visual eyepiece the iron arc spectrum could be observed to well below 3,600 angstrom units. With copper and

silver arc sources the strong lines λλ 3247, 3274 and λλ 3280, 3382, which are usually thought to be beyond the limit of visual perception, were observed by several members of the staff, using an ordinary eyepiece.

Tests of the performance of the two gratings have indicated that they give excellent definition. They are quite free from

In the type of mounting described, it is quite clear that if we use the orders on one side of the grating's central image the resultant dispersion will be the sum of the prism plus grating dispersion, whereas if we use orders on the other side, the dispersion will be the difference between that of the grating and prism. In the present case the grating is arranged to conform to the latter of these alternatives. The reason for this is that, were the former alternative followed, the angle of incidence of the light upon the grating would be quite high so the grating would only catch about half the light passing through the prism. As now used, the apertures of prism and grating are equal. In any event above 5,000 angstroms, and even lower for the second order, the dispersion of one prism is small compared to that of the grating. It is hardly necessary to point out that the dispersion of the prism rapidly increases toward the violet. The dispersion of the single prism and first order grating are equal at about λ 4000.

An idea of the increase in dispersion yielded by the gratings over the three prisms is given by Figure 4. The region shown is that near H α and the spectrum that of a neon discharge tube, our standard comparison source in the red. The uppermost of the three spectra shows also that of the star P Cygni in addition to the neon comparison lines. The dispersions of the three spectrographic arrangements at λ 6563 and λ 5893 are given in the accompanying table where the figures are those for our so-called L camera of focal length 96 cm. It is obvious, of course, that the farther toward the red and infra-red the gratings are used, the greater will be their gain over the three prisms. The theoretical resolving powers of the three arrangements are also indicated in the table.

Figure 5 shows microphotometer tracings of spectra of the stars P Cygni, α Cygni and ε Orionis in the region of the sodium D-lines taken respectively with three prisms, the first order grating and the second order grating. The tracing of ε Orionis, it may be

noted, was taken with considerably higher sensitivity of the microphotometer than were the other two. This figure demonstrates, as well as the relative dispersions of the three instruments, the structure found on second order plates of the D-lines in those stars which had exhibited complex interstellar calcium lines.[2] This

	Dispersion		Resolving Power	
	λ6563	λ5893	λ6563	λ5893
Three Prisms	34.0 A/mm.	22.0 A/mm.	20 000	32 000
First Order Grating	14.1 "	15.9 "	40 000	40 000
Second Order Grating	4.1 "	5.2 "	80 000	80 000

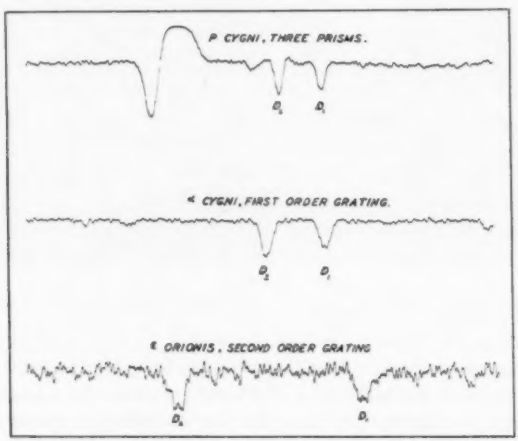

Fig. 5.—Tracings of Spectra in the Region of the Sodium D lines.

duplicity lends additional support to the conception of the existence of discrete clouds of interstellar matter with their own individual motions, previously advanced as an explanation for the structure found in the K-lines. As additional items of interest shown in this

[2]C. S. Beals, *Ap. J.*, vol. **87**, p. 568, 1938.

figure, attention might be drawn to the shallow displaced stellar sodium lines to the violet of the strong interstellar ones in the spectrum of P Cygni and to the interesting contour of the P Cygni-type line of λ 5876 of HeI. The second order grating is being used in a study of the structure of molecular bands in some late-type stars and already some interesting plates have been obtained showing partial resolution of the rotational structure of the TiO bands. The final illustration, Figure 6, shows a reproduction of a spectrogram of α Bootis near the Hα region taken with the second order grating. To give an idea of the speed of this form of the spectrograph, it may be mentioned that this plate was obtained in an exposure time of 20 minutes on an Astra VIII plate, slit width 0.025 mm. and with average seeing.

Dominion Astrophysical Observatory
Victoria, B.C.
August, 1938.

THE SIXTH MEETING OF THE INTERNATIONAL ASTRONOMICAL UNION

By Frank S. Hogg

THE sixth triennial meeting of the General Assembly of the International Astronomical Union was held in Stockholm, Sweden, on August 3-10, 1938. Twenty-eight countries were represented by nearly three hundred astronomers and one hundred and fifty accompanying guests, making a record attendance for the Union. The United States, with about ninety representatives, Great Britain with seventy, and Sweden with over sixty, supplied the largest groups. A good number of German astronomers were also present and warmly welcomed, though their country has still not felt able formally to join the Union. Canada was represented by Dr. and Mrs. J. S. Plaskett of Victoria, Dr. and Mrs. W. E. Harper and the Misses Luella and Evelyn Harper of Victoria, Professor and Mrs. C. A. Chant, Professor F. S. Hogg and Dr. Helen Sawyer Hogg, of Richmond Hill.

Professor Ernest Esclangon of Paris presided over the general meetings, and the local committee was in charge of Professor H. von Zeipel of Uppsala, and Professor B. Linblad and Dr. Y. Öhman of the Stockholm Observatory at Saltsjöbaden. For the general assemblies, meetings of the thirty-one separate commissions, information office, post office and lounge rooms, the Riksdagshuset (the House of Parliament) was put at the disposal of the Union. The building is ideally suited for such a gathering, as the chambers of the upper and lower houses served as fine large meeting rooms, while the various smaller parliamentary committee rooms were available for the separate commission discussions.

The Inaugural Ceremony was held on Wednesday morning, August 3, in the Concert Hall, when, in addition to an orchestral program, speeches of welcome were made by the Minister of Justice of Sweden, the president of the Royal Swedish Academy of Sciences, and the chairman of the Swedish National Academy of Sciences. In the afternoon the General Assembly took place in the Parliament buildings, and in the evening the Municipality of Stockholm tendered the Union a *Souper* in the famous City Hall. The buffet supper was

served in the Golden Room, a magnificent hall walled with fine golden mosaic, with great mosaic murals depicting the dramatic events of national history. Later the members inspected parts of the rest of the building, and returned to the Golden Room to enjoy a pleasant night of conversation and dancing.

Thursday morning was devoted to three one-hour sesions of sixteen separate commissions, while in the afternoon, at the invitation of His Majesty the King, a reception was held in the Royal Palace. The guests were received by Prince Gustaf Adolf, the eldest son of the Crown Prince.

Friday morning three more sessions of commissions were held, while the afternoon was devoted to a trip to Saltsjöbaden to see the Stockholm Observatory. The excursion included a very pleasant luncheon, by the Swedish National Committee of Astronomy, in the Grand Restaurant Saltsjöbaden. The members then walked up the beautifully wooded hill to the fine new observatory overlooking the sea. As well as the excellent telescopes, many pieces of auxiliary apparatus were available for inspection by the astronomers. Members of the staff explained numerous details of the work. The writer was particularly pleased to see the completed observatory, as he had had a pleasant trip out to the site with Professor Lindblad in 1930, when the building was just beginning.

On Saturday, the sixth of August, a new feature of the Union meetings was inaugurated in the form of a combined meeting of various related committees at which a group of formal papers were given, in contrast to the more informal discussion of the usual commission meetings. This combined meeting dealt with Emission Lines, and talks were given by Professor H. N. Russell, General Review of the Subject; Prof. D. H. Menzel, Chromospheres and Corona; Dr. P. W. Merrill, Emission Lines in Stellar Spectra; and Dr. H. Zanstra, Emission Lines in Nebulae and Novae. Dr. B. Lyot showed direct photographs of the corona, and films of the prominences, which were very spectacular, and called forth much discussion and enthusiasm. Other commissions, not immediately associated with this combined meeting, held their regular discussions. The afternoon was devoted to a visit to Skansen, the outdoor cultural museum of Stockholm. Here after a showing of the Zeiss Planetarium, the mem-

bers took a conducted walk through the museum, and enjoyed the exhibits of Swedish history and folk customs. A special performance of Swedish national dances was staged for the party.

Saturday evening another of the large combined meetings for formal discussion was held, dealing with the problems of galactic structure. Professor B. J. Bok spoke on the importance of star counts; Prof. B. Lindblad, on spectral types and distribution of special objects; Prof. H. Shapley on absorption phenomena and the distribution of external galaxies; Dr. F. Becker on absorption problems, and Dr. W. Baade showed his recent photographs in red light, showing the great increase in penetrating power in obscured regions obtained by such photographs.

On Sunday most of the members and guests went on an all-day excursion by steamer through the Archipelago of Stockholm. Apart from beautiful sunburns and beautiful scenery, the trip was of great scientific value in that it gave the members ample chance to discuss problems with even the most elusive astronomers, as permanent retreat was effectively impossible on a rather small excursion steamer.

Monday was devoted to an excursion to Uppsala and Old Uppsala, a pleasant trip of about an hour by train. The center of astronomical interest, of course, was the Uppsala Observatory, where again we were able to see beautiful research equipment, and discuss important programs being carried on there. In the town itself, members visited the University, thirteenth century Cathedral and the Library. In the latter, the Codex Argenteus, a beautifully preserved fifth century Gothic manuscript of the Gospels, held the attention of all the visitors. Luncheon was served in the Great Hall of Uppsala Castle, on the invitation of the University, the Municipality, and the National Committee. In the early afternoon members formed small parties and visited various sites of scientific and historical interest. One of the most delightful of these sites was the garden and home of Linnaeus. This garden is well kept up, and only those plants are included which were grown there by Linnaeus. From Uppsala we went out to Old Uppsala, and viewed the three great mounds of the early Swedish kings and the Old Uppsala church.

Tuesday morning there was again a formal colloquium for members of a number of the commissions, the subject being spectro-

photometry, and the papers were delivered by Prof. A. Unsöld and Dr. R. O. Redman. Other commissions met, both morning and afternoon, and in the afternoon there was a further showing of eclipse and other films. That evening the final Banquet of the Union was held at Hasselbacken Restaurant in Skansen Park, by invitation of the Swedish National Committee. Here again after a short program of official speeches the later part of the evening was devoted to conversation and dancing.

Wednesday morning and afternoon were given over to the General Assembly when the scientific and financial reports of the various commissions were received and adopted, expressions of appreciation for the perfect Swedish hospitality were tendered, an invitation to hold the next meeting in Switzerland in 1941 was gratefully and enthusiastically accepted, and the new officers were elected. These are *President,* Sir Arthur Eddington; *Vice-Presidents,* Prof. G. Abetti, Dr. W. S. Adams, Prof. O. Bergstrand, Prof. W. Brunner, and Prof. C. Fabry; and Prof. J. H. Oort is re-elected to fill the very exacting and burdensome office of *Secretary,* which he has so well managed in the past.

As the Draft Reports of the Commission fill a book of nearly three hundred pages, and as the complete Transactions of the meetings will fill more than four hundred pages, mostly of detailed and technical matters, it is apparent that, of course, most of the work of the Union is carried on by the method of correspondence among the various members between the triennial meetings. The meetings serve chiefly as a gathering of members to take unified action on these reports, and to allow members to discuss problems with groups of widely scattered workers in their own field. As such, this meeting admirably served its purpose.

As well as the above program, which occupied all, or slightly more than all, of the time of the astronomers present, the non-astronomical guests were supplied with various additional programs under the care of Mrs. Lindblad and Mrs. Öhman, such as visits to museums, art galleries, social service projects and industrial developments. On a number of occasions astronomers regretted being unable to attend these tours as well; this in some cases was remedied by those astronomers who stayed a few days extra, before or after the meet-

ings, to see more of the city than was possible during the meetings.

Two pleasant events outside the program were a tea on the final afternoon for the delegates from Great Britain and the Empire, at the British Legation, and an informal banquet attended by the present and recent members of the staff and students of the Harvard Observatory. Almost seventy people were present, and the meeting afforded a pleasant chance to be reunited with old collaborators, and expressed the regard with which Dr. and Mrs. Shapley are held by all those who have had the privilege of sojourning at the Harvard College Observatory.

Members of the Union attending the Stockholm meetings all deeply appreciate the perfect hospitality offered by the Swedish National Committee. The thanks of all present are due to that committee, which regulated a large and complicated gathering in a manner which left nothing to be desired. The perfect summer weather for the whole duration of the meetings, the beauty of the city and its environment, and the generous care with which all arrangements were made, and the fine scientific program combined to make the gathering one that will long be pleasantly remembered.

David Dunlap Observatory,
Richmond Hill, Ontario.

THE HISTORY OF ASTRONOMY IN CANADA

By W. E. Harper

ASTRONOMY may be said to have had its birth in the British Isles with the founding of the Greenwich Observatory. King Charles II and his advisers realized that the needs of a maritime nation required an observatory for the accurate determination of time to be supplied to the ship's chronometers. Moreover, certain observations on the positions of the moon and other heavenly bodies were necessary to provide data if mariners were to be guided aright across the seven seas. That was about the year 1660 some 278 years ago.

It is, however, just a little over a hundred years ago that the Imperial Government became concerned over the establishment of an observatory in Canada, then a colony of the Motherland. The Public Archives contain letters of date 1835 from Admiralty officials regretting that there was no observatory in the Western Hemisphere, not even in the United States. Parenthetically it should be stated however, that in this same year Professor Albert Hopkins of Williams College returned from Europe with a sidereal clock, a transit and some other instruments and that during the next few years, several small observatories were established in the Eastern States. The British Admiralty officials suggested that the instruments at the observatory at St. Helena, which was then being dismantled, be transferred to Upper Canada. In this connection the Archives report an application dated December, 1835, from a certain Professor Bonnycastle of the University of Virginia for the position of Astronomer, likely to be created. It is of interest to note the salary mentioned, for if the pound and dollar mark have not been accidentally confused, he was receiving at the University £1100 per year, a salary at which the astronomers of a century later would cast envious eyes.

Three years after the proposal of the Admiralty was made, that is to say in 1838, just one hundred years ago, hence the appropriateness of the paper at this meeting, the Astronomer Royal, Airy, reported that the instruments had all been overhauled and were ready to send forward. The financial condition of Upper Canada was not particularly rosy and so a site was acquired and the building erected

at Toronto by the Imperial authorities in 1839. At first it was primarily a magnetic observatory but among the instruments received was a 4½-inch refractor, a mural circle of four feet diameter and other smaller accessories. In 1881 there was secured a 6-inch refractor to aid in the observations of the transit of Venus the following year. During my student days the observatory was located on the south campus and the 6-inch was used to record sun-spots through pencil sketches of the projected image. These records were collated with phenomena of terrestrial magnetism and aurorae. The meteorological observatory has since been moved to the newer home of the Meteorological Service on Bloor St., but the 6-inch telescope, as well as the stone building attached to it is on the university grounds.

Similar developments to those at Toronto came a little later at Quebec, the capital of Lower Canada. The Astronomer Royal, Airy, urged the advisability of an observatory there for furnishing accurate time to mariners. In 1850 Lieut. Ashe was appointed and a small observatory was built in 1854 within the citadel. This was later transferred to the Plains of Abraham. Greenwich supplied the first instruments, while in 1864 an 8-inch refractor was bought from Alvan Clark.

In 1851 a modest observatory was built at Fredericton. This had a fine refractor by Merz and Son of a few inches aperture. Soon after its establishment Dr. Brydon-Jack determined the longitude of Fredericton by telegraph connection with Harvard.

The annular eclipse of the sun of May, 1854, which was observed at Kingston, Ont., through several small telescopes stimulated the citizens to secure a 6¼-inch refractor from Alvan Clark, which they set up along with a transit and other instruments in the public park. In 1857 the longitude was determined, using Quebec as the base, while in 1858 Donati's comet was observed. In 1860 and succeeding years an annual grant of $500 was obtained from the Government by which a better building was provided in the park. A splendid transit was also secured on loan from the Royal Astronomical Society of London, England. In 1909 the observatory was moved near the University.

While meteorological observations have been carried out on the

campus of McGill University since 1862, it was not until 1879 that the University acquired a telescope, through the gift by Charles Blackman of a 6½-inch refractor. About that time a transit instrument and a sidereal clock were also secured and accurate time, distributed through the C.P.R., has since been the principal work of this observatory.

Woodstock College had a telescope of 8¼ inches aperture, but little permanent work seems to have been done with it. Then there were several small telescopes in private hands. Miller of Toronto had one of 4 inches, now located in Victoria; Marsh in Hamilton had one of 5 inches and Wadsworth in Simcoe had a reflecting telescope of 12½ inches aperture. Then there were a number of telescopes of apertures three inches and under scattered through the country.

This gives a rapid summary of the instruments and work carried out in the early days in Canada and shows that no extensive work was attempted. Indeed it was not until the year 1885 that astronomical work of an extended nature was undertaken.

The Confederation of the Provinces into one Dominion was achieved in 1867 and one of the conditions under which British Columbia entered the Dominion was the speedy construction of a transcontinental railway. In consideration for this link with the east, British Columbia granted to the Dominion a strip 20 miles wide on either side of the railway and parallel thereto extending from the eastern boundary of the province to the Pacific Coast, a distance of somewhat over 500 miles. To survey this railway belt and tie it to the prairie sections, it was necessary to determine astronomically the latitudes and longitudes of certain points within that area. This astronomical work was started in 1885 by Otto Klotz and completed in three years, the longitude chain being extended from Seattle to Port Arthur.

During the progress of the work the desirability of having a fixed observatory for setting up and adjusting instruments was impressed upon all connected with the work. While approval was given by the Minister of the Department of the Interior to the proposal, a temporary observatory in the garden of W. F. King, then Chief Inspector of Surveys, served until a small wooden building was erected on a Government lot on Cliff St., Ottawa, about 1890.

King and those associated with him had always urged the establishment of an observatory where work other than that merely connected with surveys could be carried on. It would seem to have been his outstanding work in the preparation of the Canadian side of the case in the Alaskan Boundary award of 1893 that induced the then Minister of the Interior, The Honourable Clifford Sifton, to accede to King's request for the establishment of an astronomical observatory. In 1900 the sum of $16,000 was placed in the estimates for the construction of a building and the purchase of instruments. The next year the site on the Experimental Farm was selected and the order placed for the 15-inch equatorial and some other auxiliary instruments. In 1904 the main building was completed, the transit house and other accessory buildings a few years later. With the opening of the observatory we may consider the first stage of Canadian astronomy to have passed—a stage of isolated observations largely of a character used in survey work.

At about the same time as astronomy entered upon its second stage—that of research upon various lines—the study of astronomy in our universities also entered upon a new phase. Hitherto it had been limited to a few lectures on general principles in the mathematical departments of the universities or to instructions on the practical applications to time, latitude and longitude in the engineering schools. It was now elevated to the dignity of a separate department at the University of Toronto with Professor C. A. Chant at its head and here most of the astronomers at the three Canadian observatories received their early training in the science. It is gratifying to know that Chant's valuable services to astronomy culminated in his securing a great telescope for the university in which he laboured so effectively during the years 1890-1935.

The present writer, one of Chant's first students in astronomy, was appointed to the Ottawa Observatory in 1906, the year after it was organized under the directorship of Dr. W. F. King. The work of the observatory at Ottawa since its establishment in 1905 has been characterized by a wide range of interests. While geophysics hardly comes within the classification of astronomical work, yet it is worth noting that in seismology, or the study of earthquakes, valuable results concerning the interior of the earth have been brought to

light, first by Dr. Klotz and since by Dr. E. A. Hodgson. The magnetic survey of Canada has been actively pursued by Mr. C. A. French since 1907 and over 1,000 stations across Canada are occupied from time to time to "keep tab" upon the variation of the magnetic elements. Gravity determinations have been made by Mr. A. H. Miller at a number of stations across Canada to determine the figure of the earth but the successful application of such methods to prospecting for oil and minerals has been the principal modern development of the work. Another practical use of the observatory is that it furnishes accurate time, locally to the departmental buildings through 700 clocks controlled by a master clock in the observatory and to the country at large by means of the telegraph and wireless. Approximately 2,000 observations of star positions are made yearly which give not only accurate positions but, in due time, the proper motions of the stars. This meridian circle work was initiated and actively carried on by Mr. R. Meldrum Stewart, the present Dominion Astronomer and head of the Observatory, while its immediate supervision is now in the hands of Mr. C. C. Smith.

Observations of the rotation of the sun in a period of approximately 25 days have been carried on since 1910, first by Dr. J. S. Plaskett and Dr. R. E. DeLury and for the past 20 years by DeLury alone. The latter devised an ingenious arrangement to secure spectra from various parts of the sun at one exposure. Upwards of 200 of such nine-exposure strips of spectra are made annually and it is shown that the rotational speed at the sun's equator lies between 1.92 and 1.96 km/sec. DeLury has tried to establish a correlation between the number of sun spots and many terrestrial phenomena and while not all scientists are in agreement with him, yet he has rendered a service in compiling extensive data upon the subject.

The main work carried on with the 15-inch was the determination of the radical velocities of the stars and during the first half dozen years the orbits of a number of spectroscopic binaries were determined. With the completion of the work upon the brightest stars there arose a desire for a larger telescope to continue the work upon stars too faint to be successfully attacked by the 15-inch. The proposal that Canada should have a large modern telescope received approval from many scientific bodies and eventually the Government

acquiesced and ordered a 72-inch reflector. This was to be located in Canada where atmospheric conditions should be found most favourable. Tests made across Canada in the year 1913 resulted in Victoria being selected as the site, and thus a third stage of astronomy in Canada was ushered in.

Before treating of the big telescope era, a further word may be said about Ottawa. While the main astrophysical work shifted to Victoria the 15-inch had still a role to fill in stellar photometry. The variation in the light of certain stars, whether observed visually or photographed, as Mr. R. M. Motherwell does with a splendid 8-inch telescope, is always a worth while study and valuable information as to the real nature of such variables comes in this way.

We deal now with what may be described as the third or big-telescope age of astronomy in Canada, dating from the year 1918. While the glass disk for the 72-inch mirror was ordered in 1913 and reached the optical shops at Pittsburgh in the opening days of the Great War it was not until May, 1918, that the completed mirror enabled the programme planned for it to be put under way. That was 20 years ago.

Associated with Dr. Plaskett at Victoria in the opening years of that observatory's work were Dr. R. K. Young, now director of the sister observatory at Richmond Hill; Mr. H. H. Plaskett, now director of the observatory at Oxford University; and the writer, who is still carrying on at Victoria. Our staff has slightly increased since then, there being now five astronomers and two assistants besides the secretary and engineer. Numerous seasonal assistants have come and gone, some to accept responsible positions in other lands.

The first programme was a joint one for the four astronomers on the radical velocities of about 600 faint stars, a programme arranged in collaboration with the Mount Wilson Observatory. From half a dozen spectra of each of these the mean radical velocity of the star was obtained. In many cases the star was found to be variable in velocity, due to the fact that it was a binary, the components mutually revolving about their common centre of gravity. In the course of the radial velocity work at Victoria about 350 of these spectroscopic binaries have been discovered to date, almost exactly one fourth of the total number known.

After the completion of the first programme in 1922, a study was made of the distances of over 1,100 stars by Dr. Young and the writer. The real or intrinsic luminosities of these were derived by means of tell-tale features in their spectra. From these intrinsic luminosities, it was easy to pass to the distances through the medium of the apparent brightness of the stars concerned. An additional list of 1,230 parallaxes of Class A stars has recently been completed by the author.

Studies were also made by Dr. Plaskett of a limited group of high temperature stars of Class O. The results from 42 stars showed that these stars as a class were the most masive known with intrinsic luminosities averaging nearly 3,000 times that of the sun. In virtue of their great distances their spectra contained the narrow and stationary absorption lines of ionized calcium which originate in the widely extended cloud of interstellar matter.

Following this study a ten-year research was carried out by Dr. Plaskett and Dr. J. A. Pearce upon the radial velocities, proper motions, parallaxes and characteristics of Class B stars, next to Class O the most luminous and distant objects. Of these stars 523 were spectrographed exclusively at Victoria with an almost equal number at other observatories and their motions when critically studied yielded the following data on our galactic system.

Distance to centre	10,000 parsecs
Diameter of galaxy	30,000 "
Rotational velocity of sun	275 km/sec.
Period of rotation of sun	224,000,000 years
Mass of galaxy	1.6 x 10″ suns

An investigation by the same authors upon the motions and distribution of interstellar matter showed that, statistically at least, this finely divided material was uniformly distributed throughout the galaxy and partook of the general rotation movement. Recently Dr. C. S. Beals has gone a step further and by using high dispersion has shown that frequently the interstellar calcium and sodium lines are complex, suggesting separate condensations of interstellar material with characteristic motions of their own, yet with the same general rotational trend.

The main emphasis was originally laid upon the radial velocities

of the stars and to a lesser degree this is true to-day. Spectra are still secured with that end in view, though with the object of using such spectra for other purposes as well. Probably more attention is now given to the quality of the spectra rather than to the number secured, for studies of the physical natures of the stars call for the very best standardized spectra that can be obtained. Up to May 8 of the present year, exactly 20 years after the telescope had been put into commission, 27,917 spectra had been obtained. For the greater part of these, especially during the first seventeen years of operations, single-prism dispersion was used; latterly an increasing number with two-prism and even with three-prism are obtained, the higher dispersion permitting a more accurate determination of the profiles of stellar lines. From the character of such line profiles and the intensities of the lines comes our most reliable information as to the physical conditions existing in the atmospheres of stars.

In all up-to-date observations it is necessary to design new instruments to meet new problems. The emphasis placed upon the character of the spectrum lines in recent days called for an instrument to register mechanically the form and total intensity of such lines and Dr. Beals' design of a microphotometer has been found so useful that a similar instrument has been constructed at another leading observatory. Moreover, by a new design of a machine for measuring the displacements of spectral lines Dr. R. M. Petrie has eliminated much of the eye-strain in such operations. Through the construction by Dr. Andrew McKellar of apparatus for aluminizing the secondary mirrors of the telescope, much better spectra are now obtainable than in former days when these mirrors were silvered. It is hoped in the near future to secure equipment for aluminizing the large mirror.

The total number of radial velocities determined at Victoria is of the order of 3,300 out of about 7,500 known. It is true that a small number of our results is based upon only one or two plates, so that the velocities have not the highest precision; nevertheless the total is a creditable achievement representing as it does over forty per cent. of the known velocities. It was previously stated that about 350 of these stars were found to be spectroscopic binaries. Orbits have been determined for about 142 of these binary systems. In this connection many of the orbits earlier determined have been re-

investigated and with finer-grained plates and improved technique the secondary spectrum is quite often recorded. Where such is the case, Dr. Petrie has shown how it is possible to obtain from the profiles of the spectrum lines the relative luminosities and thus the masses of the components.

We come finally to deal with the David Dunlap observatory associated with the University of Toronto and located north of the city at Richmond Hill. The story of the founding of this, the newest of our Canadian observatories, is I think so well known that extended reference is not necessary. Briefly, it is due to the director emeritus, Professor C. A. Chant, whose life-long aim was to have such an institution serving the University for purposes of instruction and yet capable of carrying out astronomical research.

Through popular lectures on astronomy, in connection with meetings of the Royal Astronomical Society of Canada and the Extension Department of the University, Professor Chant and others had built up a community spirit of good will to the idea that Toronto should have a large observatory. One of those attending these popular lectures was Mr. David Dunlap, who became interested in the proposal but before any action on the matter was taken he became ill and passed away. After his death the project was explained to his widow who generously carried it out and thereby erected a beautiful memorial to him in building and equipping the observatory bearing his name. It was dedicated the last day of May, 1935—Chant's 70th birthday—the telescope being the second largest in the world in actual operation.

Under Dr. Young's direction the work with this 74-inch telescope has been largely the determination of the radial velocities of stars down to the eighth magnitude in the Kapteyn Areas. Some spectroscopic binaries are also being observed with a view to the determination of their orbits. As well as the spectroscopic programmes, photographs of globular star clusters are made at the prime focus by Dr. Helen Sawyer Hogg, for the purpose of discovering new variable stars, and determining light curves. With smaller telescopes the photography of meteors has been carried on and six spectra of these elusive objects have been secured by Dr. P. M. Millman. Meteor

trails are also observed visually at several co-operating stations and a total of about 15,000 has been recorded.

Although brief mention was made at the beginning to some amateur observers, the foregoing is largely a record of the work of professional astronomers. The history of Canadian astronomy would, however, be woefully incomplete if no further reference to amateur astronomers were made. Indeed if it had not been for the stimulus of the lectures on astronomy sponsored by the body of amateurs, even yet there might not have been a national observatory. The Royal Astronomical Society of Canada, started in Toronto the year after Confederation and definitely organized in 1890, has Centres now in ten cities across Canada with a total membership of 1,086. Through lectures, newspaper and magazine articles and the publication of a monthly JOURNAL, of which Professor Chant has been editor for 30 years, it does much to foster the spirit of astronomical research. In recent years members have taken to building their own telescopes and in our own city of Victoria about six reflecting telescopes from 6 to 12 inches aperture are constructed yearly. If properly directed the subsequent use of these should be productive of worth while results, supplementing the work of the professional astronomer and making Canada's future astronomical output even more worthy than its past.

In closing it should be mentioned that there is an increasing interest in astronomy in all countries. About 30,000 from all parts of the world visit the Victoria institution yearly and Canada receives much favourable publicity through the support she is giving to an institution devoted to pure scientific research.

Dominion Astrophysical Observatory,
Victoria, B.C.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

July Fireballs Observed near Bologna, Italy

The valuable meteor observations of M. Eppe Loreta, a young Italian amateur astronomer, have been reported in these pages on several occasions in the past. Among his many astronomical activities he is a most consistent observer of enduring meteor trains and their drifts, having gained a remarkable facility in the use of binoculars for this purpose. During the observations of the Aquarid shower in the latter part of July Loreta recorded a number of bright fireballs and these were also plotted by members of a group of meteor observers organized by Loreta in the Bologna neighbourhood. The names and locations of the observers are given below:

M. Eppe Loreta . .	Bologna (ϕ 44°.5 N, $\lambda 0^h$ 45.^{m}5 E).
Mme C. Corucci . .	Livorno, 134 km S.W. of Bologna.
M. R. Walter . . .	Schio, 136 km N of Bologna.
Mlle R. Calzecchi .	Porto S. Elpidio, 234 km S.E. of Bologna.
M. E. Thaiaht . .	Florence, 79 km S of Bologna.

Six bright meteors observed by this group are discussed below. The visual observations were all sent in by M. Loreta and the computations for height were made by the writer at the Dunlap Observatory, using a graphical adaptation of the Newton-Denning method.

I July 25, 1938, at 21^h 25^m G.C.T. This meteor was observed at three stations, Bologna, Livorno and Schio, the magnitude estimates being −3, 0, and −3 respectively. All three observers reported an enduring train, Loreta's plot of the change in form and drift of this train being given in Figure 1. It was visible for 1 minute with the naked eye and for 5 minutes in the binoculars (aperture 1.8 in.). The meteor was described as fast and M. Walter at Schio reported a burst though neither of the other observers noted this and it may have been an optical illusion. The plots from Livorno and Bologna agree with each other very well and these were given greater weight in the computation for height.

Height of appearance (Bologna)	136 km
" " train	91
" " disappearance	80
Length of path	80

Approximate radiant at α 22h36m, δ + 45°, altitude 45°.

The height of appearance given above is rather uncertain but the values for the train and end of path are probably reliable to within

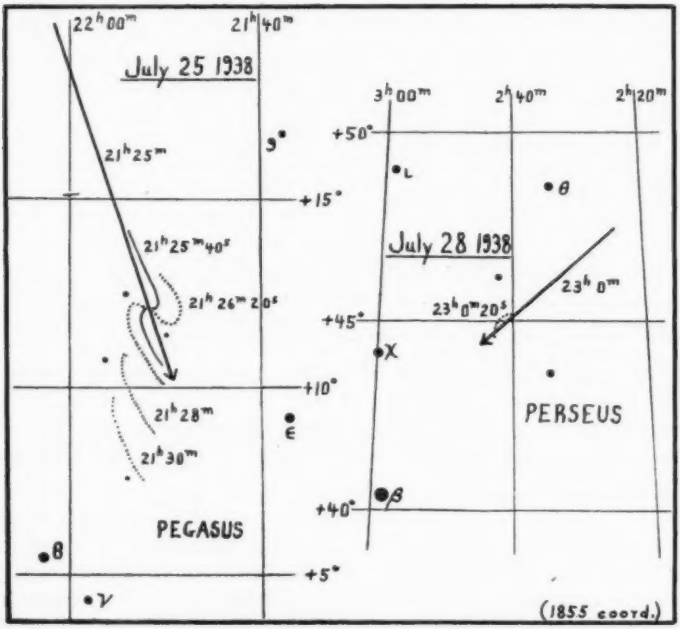

Fig. 1.—Plots by M. Eppe Loreta of the paths and trains of fireballs I and III.

two kilometres. The whole train did not drift in one direction and there was considerable evidence of cross currents, as may be seen from the plot, but the general direction of drift of the part which remained visible longest was down and to the S.E. If this motion is assumed to have been perpendicular to the line of sight

we get a minimum velocity for the train of 120 km./hr. In this case it is very likely that the true drift was much greater. A velocity of the same order of magnitude in a direction up and slightly south is indicated for the top half of the train.

II July 27, 1938, at 20^h 31^m G.C.T. This meteor was observed not far from the zenith at Bologna and Schio, magnitude estimates −1 at both stations. No reliable heights could be obtained as the Schio observation gives the meteor travelling in the wrong direction and the radiant was found indeterminant on any assumption of direction of flight. A mean height for the trail of 150 km. was obtained. A train was observed near the end of the visible path. According to Loreta this remained visible 6 sec. to the naked eye and 15 sec. in the binoculars. There was possibly a slight drift to the N.E. but this is not certain.

III July 28, 1938, at 23^h 0^m G.C.T. A Perseid, observed at Bologna and Livorno as of magnitudes 0 and 1 respectively. The plotted trails from the two stations are so nearly in the same position that they give an impossibly great height. It would seem that the Livorno plot refers to another meteor which is the more likely since its brightness was not outstanding. Loreta observed the train for 20 sec. in the binoculars and noted a slight N.E. drift. If the plot of drift is assumed accurate and the train at the normal height we get a minimum velocity of drift of about 150 km./hr., but no great weight should be placed on this value because of the brief time during which the train was visible.

IV July 29, 1938, at 19^h 58^m G.C.T. A very brilliant meteor observed at Livorno, Schio and Florence. The magnitude estimates were −4, −2, and −5 respectively. Walter observed it as "white", and Thaiaht as "yellow-green with a short red tail". On making the height computations it appeared that the first part of the path was plotted at Schio while the last part was observed at the other two stations. Height of appearance at Schio was somewhat over 150 km. and it was observed down to approximately 80 km. This is the point at which the fireball was first seen at both Florence and Livorno and it was followed down to about 50 km. altitude. None of the above heights are very accurate. The approximate

radiant, determined from the Livorno-Schio observations, was α 15^h 50^m, δ + 40°, at an altitude of 75°. Total length of path 110 km.

V July 29, 1938, at 21^h 10^m G.C.T. This meteor was observed at four stations, Bologna, Livorno, Schio, and Florence. The magnitude estimates were 0, 0, −1, and 1 respectively. The beginning and end points, determined from the four plots, are not in particularly good agreement. For Bologna, Livorno, and Florence the meteor began at a height of about 150 km and ended at 85 km. The Schio plot shows appearance at 110 km. and the end at approximately 65 km. The mean radiant, which is not well determined, was at α 21^h, δ 0°, altitude 33°. This may possibly have been an Aquarid. Loreta considered it as such and observed a train of one second duration two-thirds of the way along the visible path. He remarks that this is the first Aquarid with a train which he has observed. Mme Corucci at Livorno noted "intermittant train". Loreta's estimate of position would place the train at a height of 100 km.

VI July 31, 1938, at 21^h 06^m G.C.T. This meteor was observed at Bologna, Livorno and Porto S. Elpidio, the magnitude estimates being 1 at all stations. Loreta noted a train of 2 sec. duration and Mlle Calzecchi observed the train as most brilliant half-way along the path, the colour of the meteor as blue. The positions of beginning and ending of the visible path as computed from the three stations in pairs were in only fair agreement.

Height of appearance	155 km
" " train	115
" " disappearance	85
Length of path	170

Radiant at α 1^h 15^m, δ + 48°, altitude 24°.

The above values of height are probably accurate to within 5 km. The radiant is the best determined of any of the six meteors discussed above and may indicate some connection with the Perseids, to which shower Loreta considered it to belong.

In summary we may say that in general these bright meteors appeared at an average height of 150 km. and were followed down to about 80 km., or somewhat below this height for the brightest

objects. The one long enduring train whose height could be determined was at 91 km. altitude while the two trains of only a few seconds duration give evidence of being brightest considerably higher than this. Minimum train drifts of well over 100 km./hr. were indicated. These probably corresponded to true drifts of at least 200 km./hr.

In closing the writer would like to thank M. Loreta for his co-operation and interest and to congratulate him on the efficient organization of his group.

P. M. M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Jupiter's New Satellites

On September 12 Dr. Paul Herget, of the Cincinnati Observatory, published a general satellite solution for the motion of Jupiter X. He found that, for the short arc then available, the retrograde solution gives smaller residuals than does the solution for direct motion. Meanwhile, Dr. Nicholson has determined positions for both satellites for August 24 and 25, from Mount Wilson plates.

The news magazine *Time* interviewed Dr. Nicholson regarding possible names for these new satellites, and reports him as saying:

> It seems sure that both the new satellites go around Jupiter in reverse, so my daughter, Jean, insists one of them must be named Corrigan . . . We'll see how my astronomical associates take to Jean's idea.

In such a case could we not emulate the New York newspaper that announced Corrigan's Dublin landing in reversed type, and refer to "nagirro C"?

Contact Glasses and Sir John Herschel

Within the last few years there has been a very rapid increase in the popular interest in, and use of, "contact glasses." These are small lenses that are placed in contact with the eyeball itself, under the lid, in contrast to the conventional external eyeglasses as used for centuries. It is interesting to learn that the idea of contact glasses was first brought forward, over a century ago, by Sir John Herschel. In the April number of *The Canadian Medical Association Journal,* page 407, we read:

> The idea of contact glasses occurred first to the younger Herschel, astronomer and physicist, about 1827. Details of the experiments are lacking, but he apparently took gelatin casts of the eye, and made from these a gelatin meniscus. It was not until 1911 that Zeiss produced the first ground contact glass, followed in 1912 by a similar glass for use in cases of conical cornea.

F. S. H.

Sound from the Aurora

In this Journal for July-August (p. 313) was quoted what

seemed to be incontrovertible evidence that sound accompanied the great aurora of January 25-26 last. Indeed I think this settles the question whether or not sounds have actually been heard, and the ultra-sceptical persons who have persistently contended that all those who reported that they had heard sounds had been deceived can no longer maintain that view. As stated in the March issue (p. 157), I have been gathering evidence on this question for a long time and in 1923 (vol. 17, p. 273) I summarized it to that date. I expressed my conviction that sounds had been heard during auroral displays. In the same paper I discussed in a general way where the sound really comes from, when the auroral curtain or cloud by actual measurement is found to be sixty miles or farther away.

In the Toronto *Globe and Mail* for September 17, 1938, is a letter signed Robert R. Racey, Paris, Ont., recounting an experience he had over forty years ago. I am pleased to add it to my collection of personal testimonies. Omitting the first paragraph, the letter is as follows:

> During the winter of 1894 and 1895 I happened to be employed as a culler in the Upper St. Maurice River country, and on one particular occasion I drove all night southward from La Tuque. The ice was firm, there was little snow, the road was smooth, and my sturdy little French horse made good headway. Temperature was probably 30 degrees below zero. The atmosphere appeared to be quite clear, the heavens being brilliantly illuminated with stars.
>
> My back was turned to the north, and somewhere below the Rat River I became conscious of much light behind. I then heard prolonged, regular swishing sounds, again and again, which somewhat resembled music produced when the strings of a harp are lightly touched.
>
> On looking back, it was observed the aurora presented a periphery whose interior surface was black, while the edge was golden colored. Rays of "light" intermittently shot skyward from the edge, and each time a ray shot upward it was accompanied by the "swishing" sound, and only then was the sound audible.

This evidence is similar to that supplied by several other observers and cannot be simply brushed aside as impossible.

Odd Coincidences

During the meeting of the I.A.U. in beautiful Stockholm, when visiting a tourist agency to arrange for the passage home, two ladies came in, on the same errand as myself. Incidentally learning that I

was an astronomer and suspecting that I came from America, one of the ladies remarked that her grandfather was a professor of astronomy at Goettingen for many years. I inquired his name and the answer was, "Gauss". I asked, "Carl Friedrich Gauss"? The reply was "yes". I knew that members of his family had migrated to the United States, some going to St. Louis, and it was from this branch of the family my new acquaintance was descended. I believe Miss Gauss is engaged in social service work in Omaha, Nebraska.

Astronomers always remember Gauss as the young man of twenty-four who devised the method for determing the position of the lost Ceres and allowed it to be re-discovered on the last day of the year 1801. He was associated with Humboldt in organizing the world-wide observation of terrestrial magnetism and was the author of the absolute system of units, his name being given to one of them. But the pure mathematicians would brush these achievements aside as trivial and claim him as one of the most original and powerful workers in their own field. The author of "Men of Mathematics" calls him the "Prince of Mathematicians" and brackets together Archimedes, Newton and Gauss.

Two weeks later I was on board ship and a fellow-traveller was R. H. Babbage, a well known Montreal journalist, whose grandfather was Sir Charles Babbage (1792-1871), a famous English mathematician and mechanician. Babbage's attention was early drawn to the errors introduced into astronomical and other calculation through inaccuracies in the computation of tables, and he spent many years of his life in the construction of a calculating machine designed to overcome the faults which he found in the tables. The great machine was never completed, but he devoted much of his later years in the construction of other forms of calculating machines. Could Sir Charles revisit the earth now he would find the field of calculation dominated completely by machines. From 1828 to 1839 Babbage was Lucasian professor of mathematics at Cambridge and he was a leading spirit in founding the Royal Astronomical Society (1820) and the Statistical Society (1834). He was the first one to be awarded the gold medal of the R.A.S. (1824).

Mr. Babbage is actively collecting interesting relics of his grandfather for safe preservation for the future. He would like to learn the whereabouts of the gold medal. Mr. Babbage's address is 241 St. James St., Montreal, P.Q.

A Montreal Amateur Astronomer

I should like to compliment Mr. De Lisle Garneau on an article which appeared in a recent number of *La Revue Moderne* (Montreal). It is entitled "Les Merveilles du Système Solaire", with the subtitle "Voyage dans les autres mondes et exposé des conditions d'habitabilité" and is fully illustrated. It is well written and will be especially pleasing to our French-speaking brethren.

Mr. Garneau is the son of the well-known French-Canadian historian Mr. Hector Garneau. He is the possessor of a 4-inch refractor and is a constant observer of sun-spots and lunar occulations. We hope at some future time to print some account of his work, with reproduction of some of his sketches.

C. A. C.

Astronomical Instrument Manufacturers—A Correction

On page 363 of this Journal reference is made to a recent merging of astronomical instrument manufacturers. It should be pointed out that Sir Howard Grubb-Parsons and Company have taken over only the astronomical instrument section of Cooke, Troughton and Simms. The latter firm will continue to concentrate on the production of surveying instruments, microscopes, optical tools, etc. They also reserve the right to manufacture terresial, zenith and universal telescopes.

F.S.H.

CANADA AND COSMOS

Astronomically speaking—
Planet of our golden Sun
Shining out across the light years
Of the main galactic plane.

Geologically speaking—
Rockies not so long upheaved
To Archean gold-rich'd bedrock
O'er the wide cretaceous plain.

Geographically speaking—
Slung between the greater seas,
Continental, Northward leading,
Canada arises plain.

Unity, Sask. S. Humphry

MEETINGS OF THE SOCIETY

AT HAMILTON

June 3, 1938, Annual Field Night.—The annual (as the interval has become known) field night at the residence of Mr. W. T. Goddard was staged on the spacious lawn, where ten telescopes were set up by the members of the Hamilton Centre for the benefit of the public and as a stimulus to local interest in astronomy. While we have no observatory or planetarium in Hamilton this popular meeting-place on the outskirts of the city, under the stars and away from the bright lights, is locally known as the "Goddarium" and it was as usual well patronized.

The host and his family provided refreshments to all comers. On previous occasions home-cooking by the Goddard sisters was served by a bevy of girl friends whose presence enlivened the grounds; but on account of coming events in the home, doughnuts and coffee instead were dispensed with a liberal hand. This plan saved much labour. This annual function is so popular that in June, 1937, the "Goddarium" was besieged by 1,200 people, many of whom had little interest in astronomy. The council this year levied a 10-cent admission fee, the proceeds going to a local charity without benefit to our generous hosts.

Several out of town visitors were present, one from an adjacent centre of the Society. Our honorary president, Mrs. D. B. Marsh, graced the occasion. Her son John A. Marsh was extremely busy operating Mr. Goddard's 5-inch clock-driven equatorial, the handiwork of Mr. Marsh's father. An enclosure had been roped off and the treasurer was thus enabled to collect the dimes—over 400 of them, although it was hardly possible to correlate them with the 600 doughnuts provided.

Mr. and Mrs. Goddard were very busy attending to their numerous guests. Mrs. John A. Marsh personally saw to it that those occupied with the telescopes were served. The names of these were: Dr. W. Findlay, T. H. Wingham, W. S. Mallory, Rev. G. F. Maunsell, J. S. Taylor, H. Fox, E. E. Bossence, N. Green, C. Mason and Mr. and Mrs. Seammel. Some of these men had made their own reflectors. Mr. Geo. E. Campbell, the president, was in charge of the evening, while F. H. Butcher, W. D. Stewart and G. Larn helped in various capacities. Mr. E. G. Freeman could not attend on account of illness but gladly loaned the 8-inch reflector which he had constructed.

The sky was cloudless and the moon nearly at the first quarter so that there was no lack of objects to observe.

N. H. Broadhead, *Secretary.*

The Royal Astronomical Society of Canada

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